

# Computer Production Control—The Second Year

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A scheme of production control using a small computer has now been running in one of I.C.T.'s factories for over two years. An article in *The Computer Journal* of October 1959 (Bryen, 1959) gave an account of progress to that time. The present paper, which was given at the Harrogate Conference of The British Computer Society on 5 July 1960, describes what has been done in the second year, and demonstrates how the experience that has been gained is being used as a basis for extending the scheme on a large scale.

## Background

The Letchworth production group consists of three factories, all concerned with the manufacture of tabulators, of which there are 580 of various types scheduled for the current year. The main factory, No. 1/1, makes most of the piece parts and the large assemblies; a feeder factory, No. 1/2, makes small piece parts and assemblies; final assembly of the finished machines takes place in the third factory, No. 1/3.

The No. 1/2 factory was selected to test the pilot computer production-control scheme for several reasons. It is a small factory employing some 400 operatives, and it deals with only 2,000 part numbers, 800 of which can be called for as end-products. Demands on it arrive in bulk, three times a year, on a printed sheet, as a result of an ordinary cascade breakdown performed on conventional punched-card machinery. The throughput time is 10 weeks. This means that we have a small discrete manufacturing unit which has all the characteristics of a factory of any size, and, at the same time, is small enough to be manageable. The short throughput time means that the result of various changes in the technique of production control can be seen and evaluated reasonably quickly.

The computer used is an I.C.T. type 1201 which is, by modern standards, a relatively small, slow and cheap machine. The word time is 1.25 milliseconds and all calculations are performed in binary, using a 40-bit word. The input and output, which use 80-column punched cards and the line printer, all operate at 100 cycles per minute. Storage consists of a 1,024-word drum, and there are 4 one-word registers for calculation.

The computer performs the main routines associated with production control; these include the breakdown of end-product demands, stage by stage, into parts and raw material, the scheduling of the parts requirements which are produced as a result of this breakdown, shop loading, and stock and order control. The input to the system as a whole is a dated end-product demand on a punched card. A series of carefully phased and inter-related computer routines process this, and, at the correct time, produce the factory instructions for each operation necessary to make all the various parts and sub-assemblies needed. These operating instructions are punched out by the computer on to cards. During the course of processing, such relevant factors as shop

capacity and stock availability are considered, and information—as opposed to data—is printed out to assist various levels of the factory management.

## The Second Year's Activity

The original pilot scheme was started in August 1958, and the first year was spent in evaluating the results and making minor modifications to it. It was then decided that enough lessons had been learnt for a complete reappraisal of the scheme to be made. This involved a certain amount of reprogramming, redesign of forms and cards, and alterations to techniques. This took four months from August 1959, and the remodelled scheme was introduced in January 1960 and was running fully by March 1960. Although some of the modifications between the original Mark I scheme and the present Mark II scheme were of considerable importance, the theoretical framework on which both are based is unchanged.

## Programme Breakdown

The major difference between the Mark I and Mark II schemes is in the technique of breaking down the main programme of end products into the various sub-assemblies, piece parts and raw materials (with their requirement dates) needed to meet the main programme.

The pattern of breakdown is represented by a matrix, where the columns show the end-products and the rows all the piece parts, raw material and sub-assemblies needed for these assemblies, as illustrated in Table 1.

The figures where rows and columns intersect show the quantities of the constituent parts for one assembly.

**Table 1**  
**End Products and their Constituent Parts**

		QUANTITY REQUIRED	PIECE PARTS			SUB-ASSEMBLIES		
			A	B	C	P	Q	R
Final assemblies	X	5	10	—	5	2	—	—
	Y	7	4	3	2	1	—	2
	Z	10	—	5	1	—	2	—

For example, assembly X is composed of 10 of part A, 5 of part C, and 2 of sub-assembly P. Two of part A go direct to X, and 4 to each P.

There are two possible lines of approach for determining the total requirements of all parts. One is to hold data for each part, showing to what assembly it goes and in what quantity; the other is to hold data on the assembly showing what parts are required for it, with the required quantities of each.

The Mark I scheme of breakdown worked on the first method and a special technique was devised to deal with it. Each part had a parts master card (punched in binary) which was divided into 12 horizontal lines, one for each index point on the card, each line being split into four 10-bit sub-divisions, giving 48 fields in all. The location of the field gave the assembly concerned and the appropriate "quantity off" was punched into it. Demands for assemblies were loaded on to the drum initially in a location given by their number, and the file of parts master cards was fed in. For each part, the computer tested for punching in each field. If there was some punching, then the assembly—which was known by the field position—was found on the drum and its demand quantity was multiplied by the "quantity off" for the part. This was repeated for every assembly in which the part was used, and thus the total demand for that part was arrived at.

One question that immediately arises when considering this technique is how to deal with any free stock of sub-assemblies. In the example in Table 1, let us suppose that there are two of sub-assembly P in the stores: this fact would need to be given to the computer when it was calculating the requirement of P, so that a net figure was arrived at. However, if P is partly made up by four of part A, then a new problem arises as the net demand for A will not be  $(5 \times 10) - (7 \times 4) = 78$  but  $78 - (4 \times 2) = 70$ , and this fact is not necessarily known when processing A. Therefore, every sub-assembly would have to be treated as a final assembly for the sole purpose of dealing with these "credits" to enable a negative demand to be placed for them. The matrix now appears as in Table 2.

Table 2

Adjusted Schedule of Constituent Parts

		QUANTITY REQUIRED	PIECE PARTS			SUB-ASSEMBLIES		
			A	B	C	P	Q	R
Final assemblies	X	5	10	—	5	2	—	—
	Y	7	4	3	2	1	—	2
	Z	10	—	5	1	—	2	—
Sub- assemblies	P	—2	4	—	—	1	—	—

Now, when calculating the net demand for A, we can determine what is *not* needed. However, this does not go far enough, as none of the demands for A may be going to make P, and so we would be considering quantities of A which are already embodied in P as free stock and thus available for another sub-assembly, say R, which is patently false. To obviate this, another check would have to be made by the computer. In No. 1/2 factory there are 8 stages of assembly from raw material to most complex end-product, and a large proportion of the part numbers are, in fact, sub-assemblies. Thus to perform this type of breakdown accurately would need a fairly large internal store, because all of the negative demands for sub-assemblies would have to be kept on the drum. Also, the binary parts master file would be large as we would be interested not only in the final assemblies to which a part went, but also in all the various levels of sub-assembly.

The actual routine that was used only considered free stock of end products, allowing the intermediate stages to be overmade, kept in stores as free stock, and taken into account on the stock control run when placing factory orders against requirements.

Another difficulty with this system was that of introducing the element of production time accurately. Taking the example again, suppose that piece part B not only went to sub-assembly R, but also directly into assembly Y. Obviously those quantities of B which are needed for R must be made earlier than those which go to the final assembly. The only method of dealing with B is to ensure that it is made at the earliest time, no system of differential timing being practicable. The Letchworth system gave every part a priority code which determined its earliest requirement date, and the total demand was scheduled to be made by that date. This tends to increase the holding of finished part stocks.

The two problems of sub-assembly credits and timing both have the same effect—an increase in the value of finished parts held in stock. In factory No. 1/2 this was not considered to be too important, but the scheme is to be extended to larger factories where the throughput time is longer, hence parts would tend to be held longer, and, furthermore, the parts themselves are more valuable. It is for this reason that this method was discontinued, in spite of the great advantage of being able to do the total breakdown in one computer run. This "one-shot" technique is being used successfully where throughput times are shorter and there are fewer stages of assembly. It is particularly valuable where there is a high commonality of parts in assemblies, since the parts master file will be much smaller than the equivalent bill of material pack, and this will save input time.

The Mark II system of breakdown is of the more usual cascade type. Two computer routines are used, scheduling and programme breakdown. The most complex assemblies are taken and scheduled, that is to say, free stock is allocated against demands, and batch sizes are considered in arriving at the net demand. It is this figure which is broken down to the next level of assembly,

by associating the net demand card with a bill of material pack showing all parts needed for the assembly with the quantities off. This is then scheduled and broken down in its turn until the raw material stage is reached. During the breaking-down, not only is the quantity of each part calculated, but lead times are also taken into account to arrive at the requirement date for a part for a given assembly. If this part goes to another assembly, then another requirement for a different date is shown. Fixed priority codes are not used.

As there are 8 stages of assembly, the loop of scheduling and breakdown is done 7 times to get from the most complex assembly to raw material. This means 14 separate computer runs. This sounds somewhat cumbersome, but it is highly accurate; at every stage free stock is taken into account, and the dating at each stage ensures that all parts will be made only when they are wanted and not before. This minimizes finished part stock holding.

This change of routine has been described in some detail to bring out the point that what appears to be a good technique in theory does not always prove to be the best when used practically in a particular case. Any system must be continually reviewed and changed if necessary. A point that should be noted here is that it is vital to decide on what data will be needed and what variables should be measured to check on the effects of the system. It would be of little use to introduce a new system and not know that it was the wrong one until the factory had ground to a standstill.

Such information as (a) amount of idle time, (b) number of shortages, (c) productivity, (d) levels of work in progress, and (e) finished part stocks must be continuously obtained and compared with the past in order to see what is being achieved. The more detailed and accurate these checks are, the easier it will be to pinpoint sections of the system which need attention.

## Mark II System

The scheduling and breakdown routines are done once a month and net requirement cards are produced for all parts, dated as required in a particular fortnight, for up to 70 weeks ahead. Thus, there is a net requirement card per part per fortnight. These are then separated into made-in and bought-out items. A list of bought-out parts is sent to the purchasing department.

The net requirements of made-in parts are now loaded and a bulk load statement is produced, showing what these requirements mean in terms of hours on the machine shop. This statement shows under- and over-load for all machine groups in the appropriate period. It is a long-term management document to assist in making decisions on re-scheduling, sub-contracting, increasing or decreasing plant capacity, and so on.

Net requirements cards are then passed into the stock and order control routine known as Manufacturing Control. This is run every other day and keeps track of all stock movements, shows up errors, allocates stocks

and orders against demands, and raises fresh orders where necessary.

The orders produced are then processed on the Plant Load routine, which is carried out every two weeks. The computer loads orders on to the appropriate machine groups and punches out operation job cards. An over/underload statement is again produced, as in Bulk Load, but this time only for the next two weeks. The difference between the Bulk Load and Plant Load is not so much one of technique but of aim. In the first case, the aim is to help management make decisions to arrange for a smooth and reasonable load; in the second, the object is to produce a statement showing where the load is not smoothed, and these relatively minor fluctuations are taken care of at the foreman level by overtime working and transfer of labour from underloaded to overloaded sections, where this is possible.

## Lessons Learnt

Everyone admits that introducing a computer routine is difficult, especially for something as complex as production control. The two years spent in actually working on this system have given us a clear picture of just what these difficulties are, apart from the purely technical aspect of deciding what routines are necessary and what their scope and frequency should be.

Each part needs a great deal of data, some 30 items in all, and if just one of these is missing the part cannot be controlled properly by the computer for it will sooner or later be queried. It is far more important that an item of data such as a batch size is present, than that it is accurate. Accuracy can come later. However, certain data by its very nature is useless unless it is accurate. Examples of this are machine group capacities and operation times. The Mark I scheme started with machine capacities which were, in certain cases, highly inaccurate and this led to a great deal of trouble, for it meant that the bulk load statement was suspect, and the plant load routine produced operation job cards calling for start and finish weeks which were just not reasonable. To overcome this problem, fortnightly capacity meetings were instituted at which shop floor supervisors meet and decide what changes (if any) need be made to the previously determined capacity figures. This has had its effect and more accurate loading is now possible.

Another problem met with, in introducing a new system, is that of educating all levels of personnel in what the system is trying to achieve and how it will be used. Not enough attention was paid to this initially and the first months were bedevilled by people, through no fault of their own, making wrong decisions and taking wrong actions, because they were still thinking in terms of the previous system. This came to such a pass that it was considered worthwhile to hold a meeting of all the people concerned for one hour each day and go through, in detail, all aspects of the scheme. This again has had good results and the meetings are now less frequent and more in the nature of discussions.

The implementation period posed a series of problems of its own, especially with regard to work-in-progress. It was very difficult to calculate the load involved and to determine accurate job completion dates. An attempt was made to assess these at Letchworth, but it could only be a rough estimate due to jobs being months, or even, in some cases, years overdue. At a large factory in Castlereagh in Northern Ireland, it was decided to use the computer to produce progress lists and catch up on long-overdue jobs as a separate "cleaning up" exercise before introducing the full scheme. This aspect of the work is now nearing completion (August 1960) in one of the four Castlereagh factories.

#### Extensions

Now that the Mark II scheme has proved its worth, it has been decided to extend it to several of I.C.T.'s larger factories. Implementation in the remainder of the Letchworth group of factories starts in September 1960 and the full system is expected to be running by the middle of 1961. Plans are also drawn up to cover other factories at Castlereagh and Croydon. In fact, by the third quarter of 1962 there should be 13 factories

employing some 9,000 people under computer production control.

The machines used will be of type 1202, which is similar to the 1201 but which has 4,096 words of storage and some extra functions. This will remove many of the small difficulties met with in programming the 1201 due to its small store.

Further work is going on into a consideration of the use of second-generation computers and what the implications are, especially with regard to the use of magnetic tapes. The type 1301 computer, with its large internal store and increased speed of input, output, and processing, will undoubtedly be a useful tool in the field of production control. Consideration is also being given to the possibilities of using this machine for central data processing, for the whole of the production division, on such work as centralized breakdown and scheduling, and determining the best method of distributing demands among the various factories.

The work being done now and the ideas we have for the future owe their existence to the experience gained from the small pilot scheme which has been, and is being, of great value.

#### Reference

BRYEN, J. F. A. (1959). "The Introduction and Establishment of a System of Computer Production Control in a Light Engineering Factory," *The Computer Journal*, Vol. 2, p. 115.

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#### Conference Notice

### Automation: Men and Money

A Conference on this subject will be held at Harrogate from 27th–30th June 1961 under the aegis of the British Conference on Automation and Computation, the following organizations being responsible for the detailed arrangements.

The British Institute of Management  
The British Productivity Council  
The Department of Scientific and Industrial Research  
The Institute of Cost and Works Accountants  
The Institute of Personnel Management  
The Institution of Production Engineers  
The Tavistock Institute of Human Relations  
The Trades Union Congress

This will be the first British Conference to be organized by B.C.A.C. on the Social and Economic Effects of Automation. Enquirers should communicate with the Conference Secretary, c/o The British Institute of Management, 80 Fetter Lane, London, E.C.4.